Biotechnological modification of polyester surfaces

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Enzymes in Textile and Polymer Biotechnology

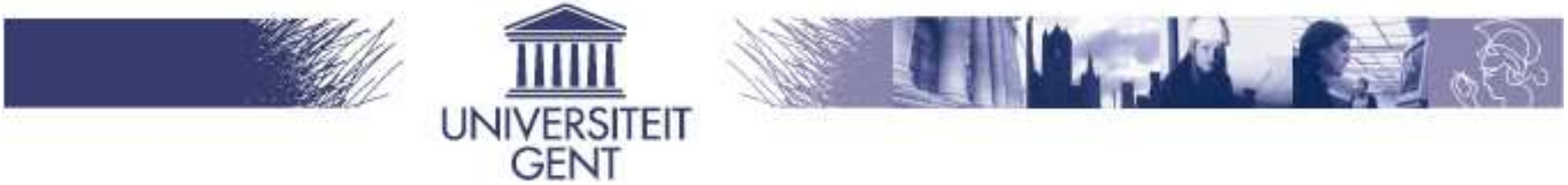
- **Vast potential in the industrial production**
  - ~200 million euros **enzymes** in textile processing
    - Industrial applications in textiles **~10 %** of the industrial enzymes
    - Detergents ~**34 %** of the industrial enzymes
    - today mainly amylases, cellulases
    - increasing importance and potential and new developments
      - pectinases, catalases, proteases, cutinases, …
      - chemo-enzymatic approaches
  - Novel technology and processes
  - BIOTEX roadmap (EuropaBio, Euratex)

Enzymes in Textile and Polymer Biotechnology

The importance and potential of biotechnology in textiles has been assessed in the last 10-20 years.

- Biocatalysis has already proven to be very profitable in industrial textile pre-treatment processes of **natural** fibers.
- Application of enzymes is not limited to biological materials:
  relatively recently it has been demonstrated enzymes are able to modify the surfaces of **synthetic** textile materials as well (PET, PA, ..).
- Synthetic fibers form an important part of the textile industry
  Global annual production (2008) of fibers and yarns was estimated (Oerlikon) to be:
  - 30.3 million tons of polyester
  - 3.6 million tons of polyamide
  - 1.9 million tons of acrylics
  - 23.6 million tons of cotton

- The production volume of PET fibers and yarns justifies research into effective production.



Biotechnological surface modification and functionalisation

Motivation

- Manipulation of **surface** characteristics is of fundamental importance in the production of functional textiles.
- Research efforts often focus on **chemical** or **physical** modification or structuring of the surfaces.
- The introduction of functionalities using **biotechnology** is a relatively unexplored and modern scientific area.
- Innovative enzymatic processes to functionalize textile surfaces

  → Need for a concerted multi-disciplinary approach.

Surface modification of PET

- surface modification to improve (yarns, films, ….)
  - hydrophilicity (wetting and absorbency) ←
    - electrostatic charge
    - dyeability
    - washability
    - wear comfort
  - improved functionalisation ←
    - coating
    - introduction functional groups
- not to change the bulk properties ←

Achieving hydrophilicity

Incorporate hydrophilic groups

- Co-polymerization
- Co-crystallisation

→ – affecting bulk properties

Generate hydrophilic groups

- Plasma treatments
- Alkali treatment

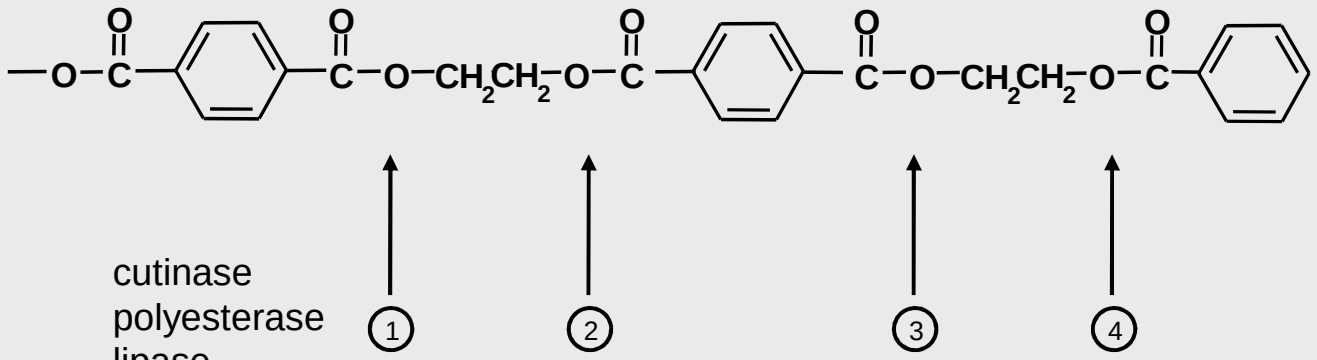
→
– strength, pitting corrosion
– hydroxide
– temperature
+ durable
+ incubation time

- Enzymes

→
+ mild reaction conditions
+ not affecting bulk properties
+ durable
– longer incubation time

Cutinase hydrolysis of PET

Model substrates, films, fabrics, yarns, fibers, oligomers

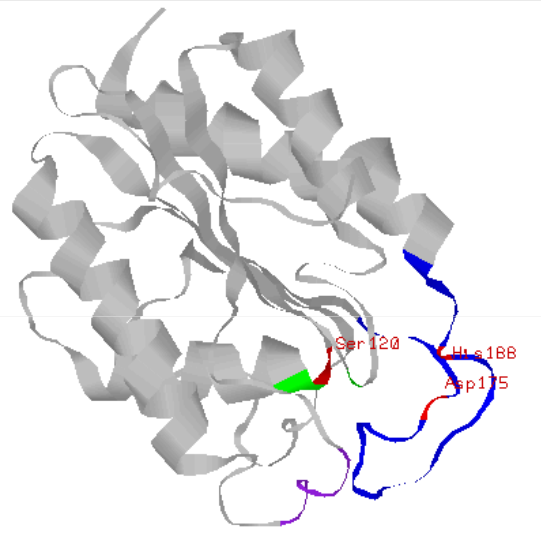


② ③ TPA (terephthalic acid)

① ④ BHET (bis(2 hydroxyethyl) terephthalate)

① ③ or ② ④ MHET (mono(2 hydroxyethyl) terephthalate)

Cutinase in PET modification



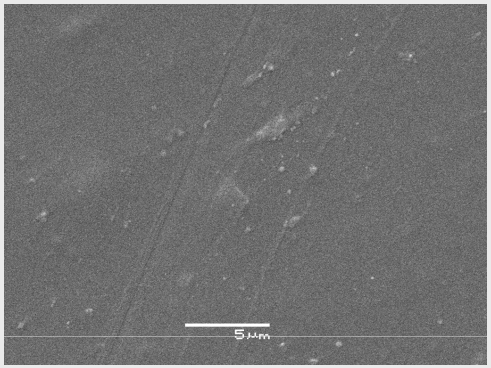
- Serine hydrolase
- 45/30/30 Å
- Ser 120, Asp175, His188
- No interfacial activation
- Absence of flap

- Cutinase exhibits significant hydrolytic activity towards amorphous regions. (ratio TPA, MHET, BHET is function of enzyme concentration and substrate)

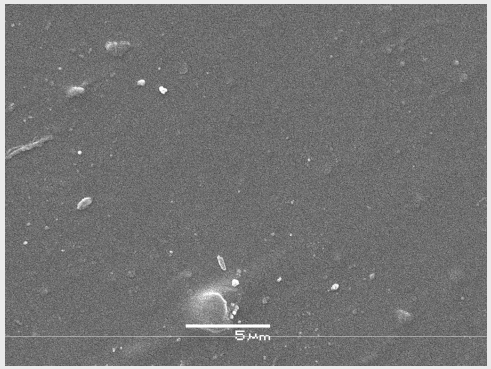
  Vertommen, M.A.M.E., Nierstrasz, V.A., Veer, M.V.D., and Warmoeskerken, M.M.C.G., J. Biotechnol. **120**(4), 376-386, 2005.

- Model substrates vs 'real' substrates
- Introduction of carboxyl and hydroxyl groups in PET surface / endo mechanism

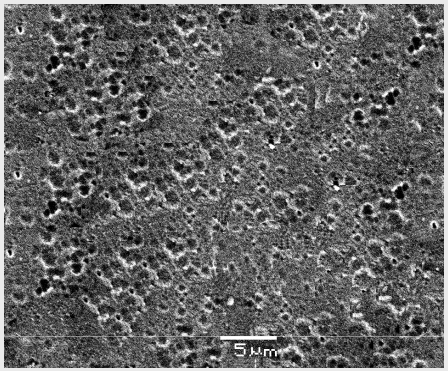
Enzymes or NaOH



untreated



cutinase 20 U/mg 2 h, 40°C

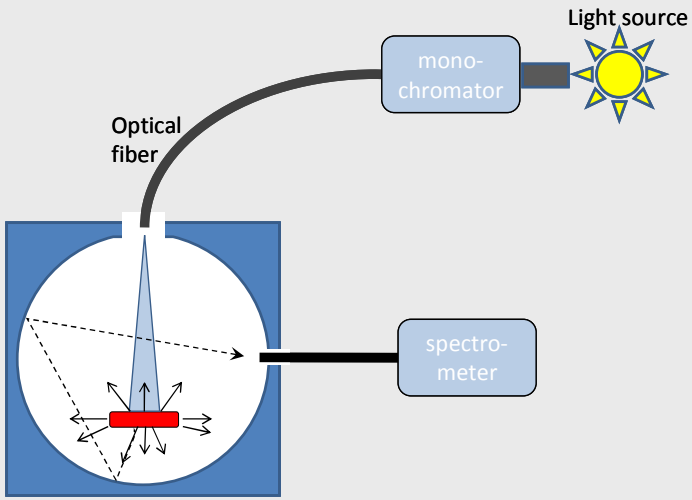


NaOH, 1M 2 h, 40°C

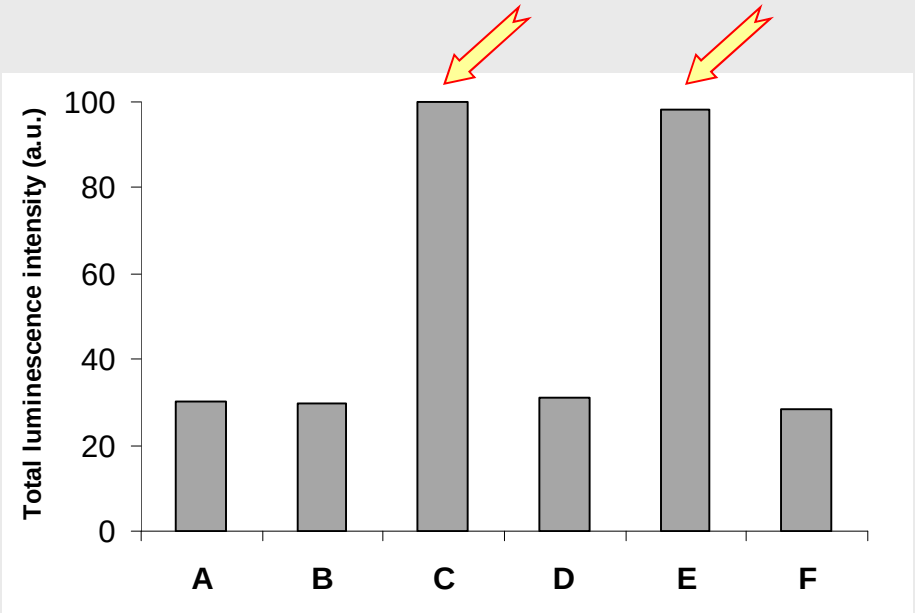
Donelli, I., Taddei, P., Smet, P.F., Poelman, D. Nierstrasz, V.A. and Freddi, G., Biotechnology and Bioengineering, 103(5), 845-856, 2009.

	Contact angle (water/PET amorphous)		
Untreated	~75		
Cutinase	~58	endo mechanism	introduction new groups
NaOH	~45	hydrolysis end groups	little or no introduction new groups

Functionalisation with 2-(bromomethyl)naphthalene (BrNP)



To evaluate the effect total photoluminescence intensity was measured using an integrating sphere.



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The emission spectra of the 6 samples (the spectra are corrected detector sensitivity).
A= PET-Cr + BrNP, B=PET-Cr + Enzyme + BrNP,
C=PET-Am + Enzyme + BrNP, D=PET-Cr + Enzyme + BrNP,
E= PET-Am + Enzyme + BrNP and F=PET-Cr + NaOH + BrNP.

Biotechnologically functionalised materials

Challenges

Today's challenge is to make the enormous potential of **modern biotechnology** for production and synthesis of materials with advanced functionalities an opportunity for textile and polymer industry.

- Novel processes for textiles exhibiting the desired functionalities.
- Novel enzyme technology for structuring and functionalisation of surfaces.

To contribute to the transition towards a biobased economy

Acknowledgements

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